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Charles Redmond
Headquarters, Washington, D.C.
(Phone: 202/755-3680)

Peter Waller
Ames Research Center, Mountain View, Calif.
(Phone: 415/965-5091)

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VENUS' GENERAL ATMOSPHERE CIRCULATION DESCRIBED BY PIONEER

Venus' predominant weather pattern is a high-speed circulation of the middle and upper atmosphere around and around the planet, from east to west, at velocities up to 362 kilometers per hour (225 miles per hour). This and other new information has emerged from a complete analysis of Pioneer Venus spacecraft data.

Superimposed on these high-velocity, planet-circling winds are lower-speed winds blowing north and southward from the equator to the poles. Wind and temperature measurements taken from the four Pioneer probes which were widely scattered over the planet indicated that these north and south winds make up a series of equator-to-pole circulation cells, stacked one on top of the other with each of the upper three cells counter-rotating as gears do.

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All of the winds in these equator-to-pole circulation loops are driven by the solar energy absorbed primarily in Venus' dense, high-cloud layer.

The whole complex of stacked circulation cells carries Venus' solar heat, absorbed near the equator, to the polar regions. Because Venus' rotation is so slow (243 days for one axial rotation), rotation forces do not break up these huge, hemisphere-spanning circulation loops as they do to similar ones on faster spinning Earth.

These two kinds of circulation, around the planet, and equator to poles, cause the atmosphere to thoroughly mix. This means it is about the same temperature and pressure at the equatorial and polar regions, and on the day and night sides.

The four Pioneer Venus probe craft measured the planet's atmosphere from top to bottom in four locations on day and night sides of the planet on Dec. 9, 1978. The Orbiter has been making pictures and other observations of the planet for the past two years and will continue to do so through 1985. All six Pioneer Venus craft (including the probe-carrying bus) arrived at the planet in December 1978.

While Venus' atmosphere behaves differently than Earth's, understanding of Venus' weather is helping with understanding such Earth weather phenomena as heat trapped by the "greenhouse effect", transport of heat to the polar regions, and interactions between the lower atmosphere and the stratosphere.

Venus' massive, planet-circling winds blow from east to west, the same direction as the very slow retrograde (backward) planet rotation. (Earth winds blow mainly west to east, the same direction that our planet rotates.)

Between altitudes of 20 kilometers (12 miles) and 65 km (40 mi), speeds of these winds range from 50 mph (80 km/hr) at 20 km (12 mi) altitude up to 225 mph (362 km/hr) at 65 km (40 mi) above the planet.

These winds represent 25 times as much atmospheric mass as the total Earth's atmosphere, but are only a quarter of Venus' enormously massive atmosphere -- 100 times as massive as Earth's. At their highest speed, these winds circle the planet once every four days.

Despite the scale of these high-speed, upper-level winds, the three quarters of Venus' atmosphere near the surface is very sluggish. From the surface up to 10 km (6 mi) altitude, wind speeds range from only 2 to 11 mph (3.2 to 18 km/hr).

In a general way, the high-speed winds can be explained by the concept that when Venus' "air" moves upward due to solar heating, it carries some momentum of the solid planet upward and, on successive passes, as the atmosphere circulates globally, the momentum accumulates at the upper levels to produce the high-speed winds. The details of this process remain something of a mystery, according to Dr. Gerald Schubert, UCLA, a Pioneer Venus scientist. Futher analysis may clarify this.

On Earth most solar energy is absorbed at the surface. However, on Venus most of the Sun's energy is absorbed in the planet's mantle of dense clouds about 50 km (31 mi) above the surface. The planet's equator-to-pole circulation is driven by these clouds. Temperature differences in the 50 km-(31 mi-) high clouds are the greatest found on the planet, a drop of 20 degrees C (68 degrees F) between the equator and 60 degrees latitude, according to Alvin Seiff, NASA's Ames Research Center, Pioneer Venus atmosphere structure investigator. This temperature range and associated pressure differences are comparable, he says, to those found at ground level on Earth. Atmospheric pressure at the altitude of the clouds on Venus happens to be about the same as that at the surface of the Earth.

As noted, Venus' equator-to-pole winds are all much slower than its round-the-planet winds and are superimposed on them resulting in winds that blow mostly around the planet, but also spiral up toward the poles.

Winds in the top half of the clouds move toward the poles; in the bottom half of the loop, Pioneer probe wind measurements showed that the winds travel in the opposite direction from poles to equator. In these clouds warmed air rises at the equator, spills over toward the poles, descends as it cools and flows back toward the equator, where it is rewarmed and goes around again endlessly.

Above the cloud level is a stratosphere cell, from 65 to 85 km (40 to 53 mi) altitude. This cell is not driven by solar heat, but is geared by friction to the cloud cell, and therefore runs in the opposite direction. Below the cloud cell, from 45 to 40 km (28 to 25 mi) is a similar sub-cloud cell, also "geared" to the cloud cell and also, therefore, running in the reverse direction to it.

Near Venus' surface, there is believed to be a surface circulation cell in the dense, sluggish lower atmosphere, driven directly by the relatively small amount of solar heat absorbed at the Venusian surface.

Between the surface cell and the sub-cloud cell, 30 to 40 km (18 to 25 mi) altitude, there may be very large eddies. According to Seiff, these eddies are probably horizontal instead of vertical because the atmosphere is stable and not convectively overturning at their altitudes.

The termination of the cloud cells at the poles seems to result in large-scale turbulence in the form of double vortices rotating around each other.

These descending vortices were unexpected, and the evidence for them is two "hot spots" rotating around each other. Seen by Pioneer infrared sensors, such hot spots are explained by Dr. Fred Taylor, Jet Propulsion Laboratory, Pioneer infrared investigator, as the result of lower, hotter levels of atmosphere made visible by holes in the clouds.

The Pioneer probe measurements showed that Venus' atmosphere is convectively overturning within the main cloud deck between 53 and 56 km (33 and 35 mi) altitude, in a layer below, and possibly in a third layer between the surface and 6 km (3.7 mi).

The rest of the atmosphere appears to be stable and not convectively overturning. In the dense clouds of the upper convective layer, 53 to 56 km (33 to 34 mi) altitude, there also seems to be local convective overturning -- in some ways like thunderstorms on Earth.

There is also evidence of "sloshing" (gravity waves) in Venus' stable layers at various places in the atmosphere -- distantly related to up and down motions of ocean waves, and driven by the rapid passage of the atmosphere from the night side to the day side and the consequent heating of the air as it enters the sunlit hemisphere.

The Pioneer Project is managed by NASA's Ames Research Center, Mountain View, CA. The spacecraft were built by Hughes Aircraft Co., El Segundo, CA.

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